Planetary Instrument Concepts For The Advancement Of Solar System Observations

Linear Mode Photon Counting HgCdTe Avalanche Photodiode Arrays for Multi-beam Laser Altimeters

Completed Technology Project (2018 - 2021)

Project Introduction

We propose to develop a 2x30 and a 7x8 pixel linear mode photon counting (LMPC) HgCdTe avalanche photodiode (APD) array for future planetary laser altimeters and infrared laser absorption spectrometers. These new detectors can detect single photon event and are about 100 times more sensitive than the silicon APDs and photomultiplier tubes used in current laser altimeters in space. The higher sensitivity and pixelated detectors will enable us to increase the number of beams by a factor of 10 compared to the current multi-beam laser altimeter, such as the Lunar Orbiter Laser Altimeter (LOLA) without increasing the laser power. The spectral response of these new detectors spans from 0.4 to 4.3 micrometers, which broaden the choice of laser wavelengths to enable penetrating atmosphere at one of the spectral transmission windows of certain planetary bodies, such as Titan. The new detectors can also be used in atmosphere backscattering lidars and laser absorption spectrometers with near quantum limited performance. These detectors are based on the recent HgCdTe APD technology developed by DRS Technologies supported by the NASA Earth Science Technology Office (ESTO). We have already developed a prototype device with 2x8 pixel in a micro cryo-cooler. Here we proposed to develop a mid-sized LMPC HgCdTe APD array for multi-beam laser altimeters with at least 10 times more beams than the current technology and pave the way for even larger pixel arrays for future 3-D imaging lidar. Laser altimeters, or lidar, have been used in numerous space missions to measure surface topography, global shape, orbit, and surface reflectance at the laser wavelength. Early planetary laser altimeters, such as the Mars Orbiter Laser Altimeter (MOLA), used a single laser beam to measure the surface elevation profile one per orbit. LOLA is the first multi-beam laser altimeters and shows the great benefit and potential of multi-beam measurements. Besides a much finer and denser ground coverage, it measures the surface slope and roughness from a single laser pulse. It also gives orders of magnitude more cross-over points for orbit and laser beam pointing determination. However the number of laser beams are now limited by the detector sensitivity, size, and the available laser power. The LMPC HgCdTe APD arrays which we propose to develop will have single photon sensitivity and combine individual detector packages into a focal plane array (FPA) to enable a LOLA sized instrument to have 10 times more beams. The United States Defense Advanced Research Projects Agency (DARPA) has already funded DRS after NASA ESTO to produce a large size focal plane array (FPA) but with a simplified read-out integrated circuit (ROIC) for ground-based flash lidar demonstration. We will leverage these investments to develop and demonstrate a 2x30 and a 7x8 pixel array detector (60 and 56 pixels) with full pulse waveform outputs. We will also study the use a single laser with microlens array to illuminate ground surface in a pattern that matches the detector pixel format. Our work plan is to (a) develop a 2x30 and a 7x8 pixel LMPC HgCdTe APD FPA with ROIC for single photon sensitivity linear outputs; (b) integrate the FPA in a low-cost liquid nitrogen Dewar system and characterize the detector performance; (c) investigate the signal waveform

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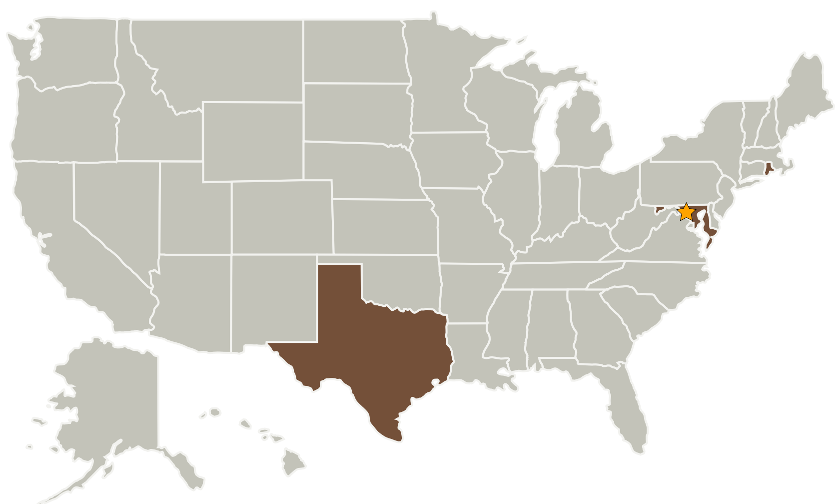
processing techniques that are efficient and can later be integrated in the ROIC, and (d) develop a laser transmitter beam formation technique to match the detector pixel patterns. The entry TRLfor the detector and the laser transmitter are TRL-2. We propose a 3-year research and development program to bring them to TRL-4. The target applications are multi-beam laser altimeters and atmosphere backscattering lidar for Mars and other planetary bodies, mid-wave infrared laser spectral absorption lidar for the Moon and asteroids, and proximity operation lidar for asteroid mapping and sample returns.

Anticipated Benefits

The new single photon detectors extend the space lidar wavelength from near to mid infrared and enable many new types of measurements, including mapping of water ice on the lunar surface and cold traps, Martian wind speed, and 3-D terrain mapping for airless bodies.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

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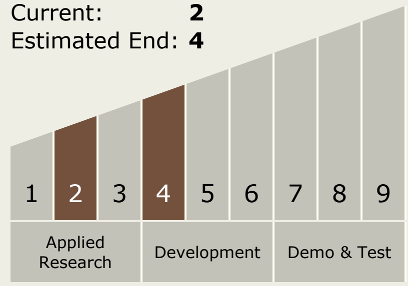
Organizations Performing Work	Role	Type	Location
⭐Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland
Brown University	Supporting Organization	Academia	Providence, Rhode Island

Primary U.S. Work Locations	
Maryland	Rhode Island
Texas	

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.5 Lasers

Target Destination

Others Inside the Solar System